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ON
ARTIFICIAL RESPIRATION
IN
STILLBORN CHILDREN.

THE AMOUNT OF VENTILATION SECURED BY DIFFERENT METHODS.

AN EXPERIMENTAL INQUIRY.

BY

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PRESENTED by the AUTHOR

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Preface.

The question whether a new-born child shall live or die is a matter of so great importance that no apology is needed for such an investigation as is here detailed; the answer to this question not uncommonly depends upon the success or failure of artificial respiration.

In spite of the importance of the subject, nothing is accurately known with regard to it, and even good text-books on midwifery pass over it superficially.

It is not proposed to deal at once with the whole matter, which is far too large for summary treatment; this object will probably be better attained by dividing the subject and treating each division in detail.

The present inquiry deals solely with the question, "What relative amount of air is each of the various methods capable of introducing into the lungs of a new-born child which has never breathed?" This question is as yet unanswered; for the various committees which have investigated the main question have hitherto confined their attention to adults, and even the interesting experiments of Behm, which were performed on six new-born children, dealt with children which had not breathed in three cases only, in one of which the experiments failed—a point which seems to have affected his results.

The present investigation, being solely experimental, elucidates many points in the physiology of the respiration of new-born children.

These experiments, dealing as they do with children in whom (for instance) the circulation is not proceeding, no doubt require translation into terms of children in whom the circulation has not yet ceased.

On the other hand, they eliminate the influence of reflex action, a most important matter where methods are to be rigidly tested, and practically of great moment where the children are in the stage of pale (flabby) asphyxia, in which reflex action is abolished, and which includes all cases of real difficulty.

This question of the stage of asphyxia is a point on which far too little stress has been laid, the facts being that almost any form of irritation may be sufficient to excite inspiratory efforts in a case of the first (livid) stage of asphyxia, whereas in the second (pale) stage, not only can reflex action not be relied on, but all forms of irritation are simply useless and waste time.

It is curious to read the correspondence which has followed the introduction of each new method of artificial respiration, the writers kindly hastening to contribute their mite of evidence in favour of the method, in the form of cases absolutely without any trustworthy details of the stage of asphyxia, and therefore absolutely worthless.

It may be perfectly true that a child can be recovered in select cases either by slapping the nates or by Silvester's method, but to put the two methods together is unphilosophical and likely to obscure rather than to elucidate the question. On the other hand, it is certain that in the only important class of cases slapping and all other forms of irritation are simple waste of time.

Many of the accounts with which the papers have been repeatedly inundated, relate to cases which would probably have recovered if simply let alone.

In order to establish a numerical superiority with regard to any one method according to this system, it would only be necessary to apply it to all children born (an argument which applies to the frequent use of the forceps).

The desiderata of a method of artificial respiration are summarised by Behm as (*a*) ventilation of the lungs, (*b*) excitation of the circulation, (*c*) removal of foreign bodies from the air passages. Of these, only the first is here considered.

It has been thought best to give a description of each method from the original source, as even the common methods are most inaccurately known.

It is not, for instance, an edifying spectacle to see one surgeon leaning his whole weight on a patient's abdomen at the same time as another surgeon elevates the arms, in the belief that Silvester's method is being pursued.

No details which secure even a small excess of ventilation of the lungs are unimportant, and a consideration of such details is included in this inquiry.

The number of bodies experimented on is twenty-six of which twenty have been used for the investigation of this portion of the subject.

The experiments were begun January 5th, 1878, and ended July 5th, 1880.

All the bodies used were those of children who had never breathed, both in order to keep within the law and also to procure uniform material for investigation.

It will be pointed out that the chest of a child which has breathed differs essentially from one which has never breathed.

It must be observed that a source of error exists in the order followed in the experiment, the subsequent experiments usually succeeding better than the earlier ones, from increasing ventilation of the lungs.

This error has been eliminated as much as possible by varying the order, and by repeating experiments after the lungs have been shown to have become expanded.

Another error exists in the stretching of the pectoral muscles which is liable to occur in Schultze's and Silvester's methods, especially the modifications of the latter.

The following methods have been employed:

1. Marshall Hall.
2. Howard.
3. Silvester.
4. Pacini.
5. Bain.
6. Schücking.
7. Schüller.
8. Schroeder.
9. Schultze.

They may be classified according to the principle on which they depend.

Classification of methods of manipulation according to their mode of action with regard to ventilation of the lungs.

The methods aim at procuring inspiration.

- I. Indirectly . .
  - By elastic recoil of the chest walls
    - 1. Marshall Hall.
    - 2. Howard.
- II. Directly
  - A. By traction
    - 1. Upward traction of the ribs, clavicles, and sternum
      - 1. Exerted through the arms; (3) Silvester; (4) Schücking.
      - 2. Exerted through the shoulders; (5) Pacini; (6) Bain.
    - 2. Upward and outward traction of the lower ribs, and consequent depression of the diaphragm
      - 7. Schüller.
  - B. By gravitation and centrifugal force
    - Elevation of the ribs, clavicles, and sternum, and depression of the diaphragm
      - 8. Schultze.
  - C. By flexion
    - Increasing capacity of cylindrical thorax by curvature of its anterior wall
      - 9. Schroeder.

Description of methods.

1. *Marshall Hall* ('Lancet,' 1856, March 1, p. 229, "On a New Mode of Effecting Artificial Respiration," by Marshall Hall, M.D., F.R.S., and April 12th, p. 393, "Asphyxia, its Rationale and Treatment.") "Let the patient be placed in the prone position, the head and neck being preserved in their proper place. The tongue

will fall forwards, and leave the entrance into the windpipe free. . . . Let the body be now turned gently on the side (through rather more than a quarter of a circle), and the pressure on the thorax and abdomen will be removed, and inspiration . . . will take place! The expiration and inspiration are augmented by timeously applying and removing alternately pressure on the spine and ribs."

(P. 394.) "Replace the patient on his face, his arms under his head, that the tongue may fall forward and leave the entrance into the windpipe free, and that any fluids may flow out of his mouth; then 1. Turn the body gradually but completely on the side, and a little more, and then again on the face, alternately (to induce respiration and expiration). 2. When replaced, apply pressure along the back and ribs, and then remove it (to induce further inspiration and expiration), and proceed as before.

2. *Howard* ('Lancet,' 1877, August 11, p. 194). P. 196: "Seize the patient's wrists, and having secured the utmost possible extension with them crossed behind his head, pin them to the ground with your left hand so as to maintain it. . . . The rest consists in throwing the weight of the body on the lower ribs, and then suddenly relieving the pressure (this of course requires modification in a fœtus). It can be practised before division of the funis or after."

3. *Silvester* ('The True Physiological Method of Restoring Persons apparently Drowned or Dead, and of Resuscitating Stillborn Children,' by Henry R. Silvester, B.A., M.D. Lond., 1858). "1. To adjust the patient's position place the patient on his back with the shoulders raised and supported on a folded article of dress. 2. To maintain a free entrance of air into the windpipe (by drawing the tongue forwards). 3. To imitate the movements of deep respiration raise the patient's arms upwards by the sides of his head, and then extend them gently and steadily upwards and forwards for a few moments. Next turn down the patient's arms and press them gently and firmly for a few moments against the sides of the chest."

In Fig. 4, p. 17, the operator grasps the arms above the elbows. The arms are not everted.

Also 'The Discovery of the Physiological Method of inducing Respiration in cases of Apparent Death from Drowning, Chloroform, Still-birth, Noxious Gases, &c.,' 3rd ed., 1853.

The directions are the same as above, except that (p. 20) the feet are to be secured; the arms are to be kept "stretched steadily" (upwards) for "two seconds" instead of "a few moments." The operator grasps the arms above the elbows, but in the figure he has seized them distally to the elbows (figs. 24 and 25).

Pacini ('Di un nuovo metodo di praticare la Respirazione artificiale,' Firenze, 1867). The feet of the patient being fixed the operator stands with the head against his own abdomen, and then with his hands takes a firm hold of the upper part of the arms, applying the forefingers behind and close to the armpit, while the thumb is in front of the head of the humerus. Holding the shoulders thus, he pulls them towards him, and then lifts them in a perpendicular direction.

5. *Bain* ('Med. Times and Gazette,' 1868, December 19th, p. 708). 1st method. The fingers are placed over the front of the axillæ, the thumbs over the ends of the clavicles; the operator then draws the shoulders upwards, and then relaxes his traction.

2nd method. The shoulders are raised by taking hold of the hands and raising the body about a foot off the table, the position of the arms being at about an angle of 45° beyond the head.

6. *Schücking* ('Berl. Klin. Wochenschr.,' 1877, No. 2, p. 19). The same as Silvester, except that the arms are drawn upwards *and outwards*.

7. *Schüller* ('Berl. Klin. Woch., 1879, June 2nd, p. 319). The operator, standing either at the left side or at the head of the patient, raises the edges of the ribs with his fingers placed beneath them, and then depresses them. The knees should be kept bent to relax the abdominal

walls. The manipulation flattens and depresses the diaphragm.

8. *Schroeder* ('Lehrbuch der Geburtshülfe,' Bonn., 1874, p. 673) suggests supporting the child by the back only, letting the arms and legs fall backwards (which will produce opisthotonos), and then bending them in the contrary direction (producing emprosthotonos). The latter to produce expiration, the former inspiration.

9. *Schultze* ('Der Scheintod Neugeborener,' Jena, 1871, p. 162). The navel string being tied, the child is seized with both hands by the shoulders in such a way that both thumbs lie on the anterior wall of the thorax, both index fingers extend from behind the shoulders into the axillæ, and the other three fingers of both hands lie obliquely along the posterior wall of the thorax. The head is prevented from falling by the support of the ulnar sides of the two hands.

The operator stands with somewhat separated legs, and bends slightly forwards, holding the child as above described at arms' length, hanging perpendicularly (1*st position, inspiratory*).

Without pausing, he swings the child upwards from this hanging position, at arms' length. When the operator's arms have gone slightly beyond the horizontal, they hold the child so delicately that it is not violently hurled over, but sinks slowly forwards and forcibly compresses the abdomen by the weight of its pelvic end (1*st movement, expiratory*).

At this moment the whole weight of the child rests on the operator's thumbs lying on the thorax (2*nd position, expiratory*).

Any compression of the thorax by the hands of the operator must be carefully avoided. The body of the child rests during the first position with the floor of the axilla on the index fingers of the operator exclusively, and no compression should be exercised on the thorax in spite of the support offered by the hands to the head, nor should the thumbs compress the thorax in front.

When the child is swung upwards, the spinal column should not bend in the thoracic but only in the lumbar region, and the thumbs should not at this time strongly press the thorax, but should only support the body as it sinks slowly forward.

The raising of the body as far as the horizontal should be effected by a powerful swing of the arms (of the operator) from the shoulders; but from that point the arms should be raised more and more slowly, and, by means of a delicately-adjusted movement of the elbow-joints and scapulæ on the thorax, the pelvic end of the child should fall gradually over. By this gradual falling over of the child's pelvis over the belly, considerable pressure of the thoracic viscera is exercised both against the diaphragm and the whole thoracic wall. At this point the inspired fluids often pour copiously from the respiratory openings.

After the child has slowly but completely sunk over, the operator again lowers his arms between his separated legs. The child's body is thereby extended with some impetus; the thorax, released from all pressure (the operator's thumbs lying now quite loosely on the anterior wall of the chest), expands by means of its elasticity; but the weight of the body hanging, as it does, on the index fingers of the operator by the upper limbs, and thus fixing the sternal ends of the ribs, is brought into use for the elevation of the ribs with considerable impetus; moreover, the diaphragm descends by virtue of the impulse which is communicated to the abdominal contents. By this means a deep inspiration is quite passively produced (*2nd movement, inspiratory*).

After a pause of a few seconds, in 1st inspiratory position, the child is again swung upwards into the previous position (*1st movement, 2nd position,* expiratory), and while it sinks slowly forwards it brings its whole weight to bear on the thumbs, which rest on the anterior thoracic wall, and mechanical expiration again ensues. At this point any inspired fluids always pour copiously from the mouth and nose, and generally meconium from the anus.

The proceeding is repeated eight or ten times a minute, but more slowly when the inspired fluids flow from the mouth and nose.

Description of apparatus.

Tracheotomy was performed, and a canula tied into the trachea, this canula being in connection with an india-rubber tube, interrupted by a **T**-piece closed by a clamp, for the purpose of admitting air when desired. (When this clamp was opened the manometer is said to have been *readjusted.*) The other end of this tube was connected with a **V**-tube filled with water to a marked point, about half-way up. Inspiration, therefore, produced a rise of the water in the limb of the tube to which the india-rubber tube was attached, and expiration a corresponding fall. The readings in inches refer to the height of the fluid in this limb above the zero or line of original level (the actual height of the column of fluid being double this), and not to the cubic amount of air inspired.

The **V**-tube was not long enough to register more than six or seven inches above the line of zero; when the effect exceeded this, the manometer was readjusted half way, the subject being held in *statu quo.*

These facts do not vitiate the comparison of the relative inspiratory value of each different method, but they would have to be remembered in calculating the absolute inspiratory value.

Each inch in length of the manometer tube held about 2 c. c.

The results in the same body only are compared.

Exp. 1.—Male child, at eighth months. Craniotomy, January 5th, 1878, 9 p.m.; experiment, January 9th, 10 a.m. (83 hours). Trachea divided, canula tied in, tube connected with water manometer.

1. Lungs not inflated.

$$\left.\begin{array}{l} a.\ \text{Marshall Hall} \\ b.\ \text{Silvester} \\ c.\ \text{Schroeder} \end{array}\right\} = 0$$

$$d.\ \text{Schultze} \quad = \text{rise } \tfrac{1}{4} \text{ in.}$$

2. Upper and lower parts of trachea connected by a canula which was tied in, so as to restore the continuity of the trachea. Head bent back, lungs inflated by mouth to mouth method. (N. B.—Considerable force was required.) Experiments failed, the lungs had been burst by mouth to mouth inflation.

Exp. 2.—Male child, prematurely born at seventh month. Partial placenta prævia ; heart beating at birth, but no respiratory efforts. Birth at 1 a.m. March 29th, 1878 ; experiment March 30th, 1 p.m. (36 hours). Tracheotomy, canula in trachea, connected with manometer, lungs inflated through tube.

1. *Marshall Hall.*—Simple change of position in this method produced only the slightest oscillation. Thoracic pressure produced $\frac{1}{4}$ inch fall. Thoracic and abdominal pressure produced $\frac{1}{2}$ inch fall.

On putting the child into the expiratory position, applying thoracic and abdominal pressure, and connecting the manometer afresh, relaxation of the pressure produced a rise of a quarter of an inch, very slightly increased on turning the child into the inspiratory posture.

2. *Silvester.*—(*a.*) Without previous pressure on thorax or abdomen. Inspiratory movement produced $1\frac{1}{2}$ inch rise. Abdominal and thoracic pressure produced $\frac{1}{2}$ inch fall.

(*b.*) After applying thoracic and abdominal pressure, manometer was readjusted. Inspiratory movement = 2 inches rise.

3. *Schroeder.*—No change except $\frac{3}{4}$ inch fall with extreme opisthotonos, $\frac{1}{4}$ inch fall with extreme emprosthotonos.

4. *Schultze.*—(*a.*) Expiratory movement expelled $\frac{5}{8}$ inch, inspiratory movement inhaled $\frac{1}{2}$ inch ; on hanging the body by the forearms $1\frac{1}{8}$ inch was inspired.

(*b.*) Inspiratory movement inhaled 1 inch. On hanging the body by the forearms stretched outwards and backwards, as in Silvester's method the total inspiration =4½ inches.

(*c.*) After reinflation of the lungs. Expiration expelled 2 inches. Inspiration by the combined (Schultze-Silvester) method as above (*b*) inhaled 1 inch.

(*d.*) After reinflation of the lungs. Expiration = 2 inches. Inspiration (Schultze-Silvester) =3½ inches.

After many experiments it was evident that though the maximum and minimum changes varied, the Schultze-Silvester method (as above) produced much more change than other methods.

		Maximum inspired.
Order 1.	Schultze-Silvester	4½ inches.
2.	Silvester	2 ,,
3.	Schultze	1 ,,
4.	Marshall Hall	¼ ,,
5.	Schroeder	fall in all cases.

Exp. 3.—Female child, full time; accidental hæmorrhage. Born April 6th, 1878, at 10 p.m; experiment April 8th, 1878, 2 p.m. (40 hours). Tracheotomy, canula in trachea, lungs inflated through tube of manometer.

1. *Marshall Hall.*—Simple change of posture produced only a slight oscillation. Expiratory posture with thoracic pressure produced ¼ inch fall. Expiratory posture with thoracic and abdominal pressure produced 1 inch fall. Relaxation of this pressure produced a rise of ¼ inch, sometimes very slightly increased, but oftener slightly diminished by turning child on its back.

2. *Silvester.*—(*a.*) Without thoracic or abdominal pressure. Inspiratory movement =1½ inch rise. Abdominal and thoracic pressure produced ½ inch fall (below zero).

(*b.*) Abdominal and thoracic pressure applied, manometer readjusted. Inspiratory movement =2 inches.

3. *Schroeder.*—Extreme opisthotonos produced ⅛ inch fall. Extreme emprosthotonos produced ⅜ inch fall.

4. *Schultze.*—(*a.*) Expiration = 3 inches fall. Mano-

meter readjusted. Inspiration = 1 inch rise. On repeating the experiment several times without readjusting manometer, the column fell three inches on expiration, and rose 1 inch on inspiration.

(*b.*) Combined Schultze-Silvester produced 1½ inch rise.

(*c.*) Inspiration (as described by Schultze) produced 1 inch rise. On hanging body by forearms (Schultze-Silvester) the total inspiration reached 1¾ inch.

(*d.*) Extreme opisthotonos in the position of inspiration produced a fall of ½ inch, apparently from overstretching of the anterior abdominal walls, by which they were approximated to the spine.

5. *Howard.*—On relaxing pressure the column rose very slowly ¼ inch, the thoracic walls very slowly altering their shape, their expansion lasting for one minute.

		Maximum inspired.	
Order 1.	Silvester	2 inches.	
2.	Schultze-Silvester	1¾ ,,	
3.	Schultze	1 ,,	
4.	Marshall Hall	¼ ,,	+
5.	Howard	¼ ,,	
6.	Schroeder	fall in all cases.	

Exp. 4.—Female child, full time. Born April 14th, 1878, 7 p.m.; experiment April 15th, 3 p.m. (20 hours). Tracheotomy, &c., lungs inflated.

1. *Marshall Hall.*—(*a.*) Simple change of posture produced only slight oscillation.

(*b.*) Expiration with thoracic pressure = 3½ inches fall.

(*c.*) Expiration (subsequently) with thoracic and abdominal pressure = 2 inches fall.

(*d.*) Thoracic and abdominal pressure applied, and manometer readjusted. Relaxation of pressure produced a rise of ¼ inch, which was not increased on turning child into inspiratory posture.

2. *Silvester.*—(*a.*) Without previous thoracic and abdominal pressure only slight oscillation produced.

(*b.*) Thoracic and abdominal pressure applied, and manometer readjusted; result of Silvester's method = only slight oscillation.

3. *Schroeder.*—Extreme opisthotonos produced a slight fall which emprosthotonos increased to 1 inch, and which diminished to a fall of ¼ inch on repeating the opisthotonos.

4. *Schultze.*—(*a.*) Expiratory movement caused ½ inch fall. Manometer readjusted. Inspiratory movement caused ¼ inch rise. On repeating this experiment several times the amount of rise and fall increased until inspiratory movement caused 1 inch rise, and expiratory movement 2 inches fall.

(*Note.*—The cause of this was probably clearing the air-passages of mucus, and increasing expansibility of the lungs.)

(*b.*) On repeating the above without readjusting the manometer, the column, after many trials, fell 3 inches on expiration, rising only to level on inspiration.

(*Note.*—Thus the total change agrees with that of the first experiment (*a*), amounting to 3 inches in both cases.)

(*c.*) Inspiratory movement combined with hanging child by forearms (Schultze-Silvester) produced a rise of 1¼ inch.

(*d.*) Inspiratory movement (ordinary) produced a rise of ½ inch; on hanging child by forearms this was increased to nearly 1 inch; on bending the body backwards (opisthotonos) the amount was reduced to ½ inch, apparently from over-stretching of abdominal walls.

Note 1.—The column rose violently with Schultze's method, overshooting the level permanently maintained. This violence was seen in no other method.

Note 2.—During the employment of Schultze's method great care was taken to avoid stretching of the tube; stretching of the tube produced *rise* of the fluid, from rarification of the air.

5. *Howard.*—Inspiration = ¼ inch or a little more, the thorax took ¾ minute to expand, which it did very slightly.

		Maximum inspired.
Order 1.	Schultze-Silvester	1¼ inch.
2.	Schultze	1 ,,
3.	Howard	¼ ,, +
4.	Marshall Hall	¼ ,,
5.	Silvester	0
6.	Schroeder	fall in every case.

Exp. 5.—Male child, full time. Placenta prævia; stillborn, without inspiratory efforts or artificial attempts. Born May 17th, 1878, 1 p.m.; experiment May 18th, 4.30 p.m. (27½ hours). Manometer connected. No inflation of lungs.

1. *Marshall Hall* = 0.

2. *Silvester.*—Inspiration (1) = 1¼ inch, (2) = 1¾ inch, (3) = 2½ inches. Expiration restored level of manometer.

3. *Schroeder.*—Inspiration = 0. Expiration = ¼ inch fall.

4. *Schultze.*—(*a.*) Inspiration varied from 1 to 2½ inches. Expiration restored level of manometer.

(*b.*) On letting body hang by forearms (Schultze-Silvester), inspiration reached four inches.

(*c.*) Abdominal and thoracic pressure produced not more than ¼ inch fall.

		Maximum inspired.
Order 1.	Schultze-Silvester	4 inches.
2.	Schultze	2½ ,,
3.	Silvester	2½ ,,
4.	Schroeder	0
5.	Marshall Hall	0

Exp. 6.—Male child, full time. Breech presentation. Born June 24th, 1878, 1 a.m.; experiment June 26th, 1 p.m. (60 hours). Manometer adjusted, lungs inflated.

1. *Marshall Hall.*—Expiration = ¾ inch fall. Inspiration = 0.

2. *Silvester.*—(*Note.*—Very forcibly performed, the force exceeding that which could be safely used to a living

child.) Inspiration (1) = ½ inch, (2) = 1¾ inch, (3) = 2¼ inches, (4) = 3½ inches, (5) = 4 inches, (6) = 4½ inches. Expiration in each case restored the level of the manometer.

3. *Schroeder.*—Opisthotonos produced slight oscillation. Emprosthotonos = ¼ inch fall.

4. *Schultze.*—(*a.*) Manometer readjusted during inspitory position. Expiration = 1 inch fall. Inspiration = ½ inch rise.

(*Note.*—The fluid rose to 1 inch, but this was not maintained, the action was rapid and violent in all cases.)

(*b.*) Manometer readjusted while child was held in expiratory position. Inspiration rose gradually from ½ inch to four inches, but not more than 1¾ inch was maintained. Expiration restored level of fluid.

(*c.*) Manometer readjusted between expiratory and inspiratory movements, so as to equalise pressures. Expiration = ½ inch fall. Inspiration = 1 inch rise.

(*d.*) Inspiratory movement completed by hanging body from forearms (Schultze-Silvester). Inspiration = 2½ inches (permanent). Expiration restored level of fluid.

5. *Howard.*—Produced the merest oscillation.

	Maximum inspired.	
1. Silvester (forcible)	4½ inches.	
2. Schultze	4 ,,	(level never maintained).
3. Schultze-Silvester	2½ ,,	
4. Schroeder	0	
5. Marshall Hall		
6. Howard		

Exp. 7.—Male child, full time (?). Cæsarian section June 24th, 1878, 5.30 p.m.; experiment June 26th, 2.30 p.m. (45 hours).

A. Manometer adjusted; lungs not inflated.

1. *Marshall Hall.*—Results = 0.

2. *Silvester.*—Inspiration gradually reached ½ inch. Expiration restored level of fluid.

3. *Schroeder.*—Produced slight oscillation.

4. *Schultze.*—The same.

B. Lungs were inflated. No method produced results.

No conclusions can be derived from this series of experiments.

Exp. 8.—Male child at eighth month. Breech presentation. Born October 11th, 1878, 7 p.m.; experiment October 13th, 11 a.m. (40 hours). Body, which was cold and stiff, thawed in warm water. Manometer adjusted; lungs not inflated.

1. *Marshall Hall.*—Results = 0.

2. *Silvester.*—(*a.*) On raising arms above head, as soon as abdominal and thoracic walls became tight the fluid was depressed. This was repeated several times.

(*b.*) On fixing feet and applying considerable force to the upper limbs, the fluid rose with one bound to 4 inches, falling on expiration to 1 inch (above zero).

(*c.*) On repeating this experiment, the manometer being readjusted, the fluid rose to 5 inches; expiration restoring its level.

(*d.*) &c., &c. In many subsequent repetitions the fluid rose to 5 inches on inspiration, falling either to one inch above zero, to zero, or to 1 inch below zero on expiration.

(*e.*) Strong abdominal pressure produced a further fall of 1 inch.

(*Note.*—Towards the end of this experiment loud whistling was heard at the root of the neck, due to mediastinal emphysema and pneumothorax. This vitiates the experiment.)

3. *Schroeder.*—Opisthotonos and emprosthotonos both produced slight fall of the fluid.

4. *Schultze.*—Inspiration by degrees reached 3 inches.

(*Note.*—This is remarkable considering the presence of pneumothorax.)

No results can be deduced from this series of experiments.

Exp. 9.—Male child, full time. Breech presentation, large size. Born November 26th, 1878, 9.30 a.m.; experiment November 27th, 1878, 9.30 a.m. (24 hours). Double talipes varus; spina bifida. Body very cold and stiff, thawed in hot bath. Manometer adjusted, lungs not inflated.

1. *Marshall Hall.*—(*a.*) Body turned on face with block under thorax; thoracic and abdominal pressure produced ½ inch fall; on readjusting manometer and relaxing pressure $\frac{1}{12}$ inch rise; on then turning body into inspiratory position ¼ inch rise.

(*b.*) Simple change of posture without pressure produced only slight oscillation.

2. *Silvester.*—A. No pressure on thorax or abdomen. Inspiration (arms rotated *in*wards) = ¼ inch. Inspiration (arms rotated *out*wards) = ½ inch. Pressure on thorax and abdomen produced ¼ inch fall.

B. Manometer readjusted during pressure on thorax and abdomen. On relaxing this pressure, fluid rose ¼ inch. On raising arms rotated *in*wards, slight additional rise was produced. On raising arms rotated *out*wards, the rise reached ¾ inch.

C. Legs were held and arms forcibly raised rotated *in*wards, rise = 6 inches. Rotated *out*wards, rise = 8 inches.

(*Note* 1.—The manometer would not register more than 6 inches, the rise of 8 inches was estimated by readjusting manometer midway.

Note 2.—The outward rotation of arms of course rendered the pectoral muscle tenser.)

D. *Marshall Hall.*—Repeated under the more favourable conditions of lungs already expanded, produced no better results than before.

E. *Schultze.*—A. The child being held in inspiratory position. (*a.*) Expiration produced 1 inch fall.

(*b.*) Pressure applied to thorax and abdomen produced a fall of one inch; this was not increased by throwing child into expiratory posture.

(*Note.*—*i.e.* Schultze's expiratory posture produced results equal to pressure on thorax and abdomen.)

B. Child being held in expiratory posture manometer was readjusted. Inspiration rose in subsequent experiments gradually from ½ to 5½ inches. Expiration restored level of fluid.

C. Child suspended by arms at the end of inspiratory movement (Schultze-Silvester). Inspiration = 7 inches.

(*Note.*—Manometer was readjusted at the end of Schultze's inspiratory movement, and before the child was suspended by the arms.)

4. *Howard.*—Inspiration = ⅛ inch rise.

		Maximum inspired.	
Order 1.	Silvester (forcible)	8 inches.	
2.	Schultze-Silvester	7 ,,	
3.	Schultze	5½ ,,	(level never maintained).
4.	Marshall Hall	¼ ,,	
5.	Howard	⅛ ,,	

EXP. 10.—Female child, said to have died in utero after a blow on the mother's abdomen two weeks before term. The child was small and seemed more than two weeks before term. Born December 16th, 1878, 5 a.m.; experiment 2.30 p.m. (6½ hours). Manometer adjusted; lungs not inflated.

1. *Marshall Hall.*—(*a.*) Pressure along the back in the prone position with a block under the thorax produced ¼ inch fall.

(*b.*) Manometer readjusted and pressure relaxed; oscillation.

(*c.*) On then turning body into inspiratory posture = ¼ inch rise.

(*d.*) Inspiration without previous pressure = ¼ inch rise.

2. *Silvester.*—A. No previous pressure on thorax and abdomen.

(*a.*) Inspiration (arms rotated *in*wards) = ¼ inch rise.

(*b.*) Inspiration (arms rotated *out*wards) produced at first ¾ inch rise, which increased gradually in repeated experiments to 2¼ inches.

B. Thoracic and abdominal pressure, manometer readjusted.

(*a.*) Pressure simply relaxed = ⅛ inch rise.

(*b.*) Inspiration (arms rotated *in*wards) = total rise of ¼ inch.

(*c.*) Inspiration (arms rotated *out*wards) = 2½ inches rise.

(*Note.*—This rise of 2½ inches occurred suddenly, and with a sort of rhonchus as if the air had forced its way past a plug of mucus.)

C. Legs held and arms forcibly elevated.

(*a.*) Arms rotated *in*wards = 5 inches rise.

(*b.*) Arms rotated *out*wards = 5 inches rise.

D. Abdominal and thoracic pressure; manometer readjusted before each experiment.

(*a.*) Arms rotated *in*wards = 8 inches rise.

(*b.*) Arms rotated *out*wards = 8 inches rise.

(*Note* 1.—Manometer readjusted midway.

Note 2.—This proves that the external or internal rotation of the arms is not of importance when enough force is applied to raise the shoulders, &c., to their highest possible position.)

3. *Marshall Hall.*—Repeated under the more favourable conditions of inflated lungs. Inspiration = ¼ inch rise.

4. *Schultze.*—A. Body held in inspiratory position.

(*a.*) Expiration = oscillation.

(*b.*) Pressure on thorax and abdomen = oscillation.

B. Body held in expiratory position, manometer readjusted. Inspiration gradually increased up to 8 inches. Expiration restored level of fluid.

(*Note.*—At this point a leak occurred, necessitating the cessation of the experiment.)

	Maximum inspired.
Order 1. Schultze 2 Silvester (forcible)	8 inches (level never maintained with Schultze's method).
3. Marshall Hall	¼ inch.

Exp. 11.—Large male child, full time. Born January 1st, 1879, 10.30 a.m.; experiment January 3rd, 12 noon (49½ hours). Body very cold and stiff, thawed in hot bath. Manometer adjusted; lungs not inflated.

1. *Marshall Hall.*—(*a.*) Thoracic and abdominal pressure in prone position with a block under thorax produced ¼ inch fall.

(*b.*) Manometer readjusted, and pressure relaxed, fluid rose ⅛ inch.

(*c.*) Child turned into inspiratory posture, total rise =⅜ inch rise.

(*d.*) Simple change of posture without previous pressure produced ¼ inch rise.

2. *Silvester.*—A. No previous pressure—inspiration.

(*a.*) Arms rotated *in*wards = total ⅜ inch rise.

(*b.*) Arms rotated *out*wards =1 inch rise.

B. Pressure on thorax and abdomen, manometer readjusted.

(*a.*) Pressure simply relaxed =⅛ inch rise.

(*b.*) Arms raised, rotated *in*wards = total ⅜ inch rise.

(*c.*) Arms raised, rotated *out*wards = total ⅛ inch rise.

C. Legs held and arms very forcibly elevated, after thoracic and abdominal pressure.

(*a.*) Arms rotated *in*wards = 10 inches rise.

(*b.*) Arms rotated *out*wards = 11 inches rise.

D. Legs held and arms very forcibly elevated without previous thoracic and abdominal pressure.

(*a.*) Arms rotated *in*wards = 9 inches rise.

(*b.*) Arms rotated *out*wards = 10¾ inches rise.

(*Note.*—Manometer readjusted midway).

3. *Marshall Hall.*—Was tried again under the more favourable circumstances of the lungs having become expanded. Pressure on thorax and abdomen, manometer readjusted.

(*a.*) On relaxing pressure, rise =¼ inch.

(*b.*) On turning child into inspiratory posture, total rise = ⅞ inch

4. *Schultze.*—A. Child being held in inspiratory position and manometer readjusted between the experiments.

(*a.*) Expiration gradually increased to 3½ inches fall.

(*b.*) Thoracic and abdominal pressure in supine posture produced 2½ inches fall.

B. Child held in expiratory posture, manometer readjusted; child then thrown into inspiratory posture. Inspiration = 7 inches. Expiration restored level of fluid.

C. The same experiment, the child being finally suspended by its arms (Schultze-Silvester). The total inspired was not increased = 7 inches.

Order		Maximum inspired.
1.	Silvester (forcible)	11 inches.
2.	Schultze-Silvester	7 ,,
3.	Schultze	7 ,,
4.	Marshall Hall	⅞ ,,

Exp. 12.—Full-grown female child. Delivered by forceps January 17th, 1879; experiment January 24th (7 days). Body, which was cold and stiff, was thawed in hot bath. Manometer adjusted; lungs not inflated.

1. *Marshall Hall.*—(*a.*) Thoracic and abdominal pressure applied in the prone position with a block under the thorax produced a very slight fall.

(*b.*) Manometer readjusted and pressure relaxed, rise of ⅛ inch.

(*c.*) Child turned into inspiratory posture; total rise = a little more than ⅛ inch.

(*d.*) Simple change of posture without previous pressure produced only slight oscillation.

2. *Silvester.*—A. No previous pressure on thorax or abdomen.

(*a.*) Inspiration (arms rotated *in*wards) = ⅝ inch rise.

(*b.*) Inspiration (arms rotated *out*wards) = ⅛ inch rise.

(*Note.*—Something seemed to be obstructing the air passages.)

B. Forcible elevation of the arms, legs being fixed.

(*a.*) Arms rotated *in*wards; the fluid rose on repeated attempts to 7 inches.

(*b.*) Arms rotated *out*wards; on repeated attempts fluid reached 8 inches.

(*Note.*—Manometer readjusted.)

c. Legs not fixed; pressure on thorax and abdomen preceding manipulations.

(*a.*) Pressure simply relaxed = slight oscillation.

(*b.*) Arms rotated inwards = ¾ inch rise.

(*c.*) Arms rotated outwards = 1¼ inch rise.

3. *Marshall Hall.*—Repeated after presumable expansion of lungs.

(*a.*) Pressure relaxed = oscillation.

(*b.*) Child turned into inspiratory posture = ⅛ inch rise.

4. *Schultze.*—A. Child held in inspiratory position. Expiratory movement caused fall, gradually increasing to 1½ inch.

B. Child held in expiratory posture and then thrown into inspiratory position. Inspiration after several attempts reached 7 inches, but not more than 2 inches was maintained; expiration restored level of fluid.

C. The same, the child finally suspended by its arms (Schultze-Silvester). No increase of air *permanently* retained, *i.e.* 2 inches.

		Maximum inspired.	
Order 1.	Silvester (forcible)	8 inches.	
2.	Schultze	7 „	(level never maintained).
3.	Schultze-Silvester	2 „	
4.	Marshall Hall	⅛ „	

Exp. 13.—Large male child. Born February 26th, 1879, 6 a.m; experiment February 28th, 12.30 p.m. (54½ hours). Body very cold and stiff, thawed in hot bath. *Mercury* manometer, no inflation of lungs.

1. *Marshall Hall.*—Thoracic and abdominal pressure applied in the prone position with a block under the thorax.

(*a.*) Pressure relaxed = slight oscillation.

(*b.*) Child turned into inspiratory posture = no increase of effect.

2. *Silvester.*—A. No previous pressure.

Inspiration.

(*a.*) Arms rotated *in*wards = slight oscillation.

(*b.*) Arms rotated *out*wards = slight oscillation.

B. With previous pressure. Nothing but slight oscillation produced.

C. Legs fixed, arms forcibly raised.

(*a.*) Arms rotated *in*wards = ½ inch rise.

(*b.*) Arms rotated *out*wards = ½ inch rise.

3. *Schultze.*—A. Inspiration repeated several times eventually produced a rise of more than 1 inch. Expiration restored level of fluid.

B. The same, the child finally suspended by arms. Inspiration = 1 inch (as before).

4. *Silvester.*—Repeated after some presumable expansion of lungs (legs fixed, arms forcibly raised), produced the same results as above (2 C).

N.B.—Mercury manometer.

		Maximum inspired.
Order 1.	Schultze	1 inch.
2.	Schultze-Silvester	
3.	Silvester (forcible)	½ ,,
4.	Marshall Hall	0

Exp. 14 (G.).—Male child, full time, breech presentation. Born November 30th, 1879, 8 a.m.; experiment December 1st, 1.30 p.m. (29½ hours). Body very cold and stiff, thawed before fire.

A. Manometer adjusted, no inflation of lungs. Long wooden pointer stuck into liver, to mark descent of diaphragm.

1. *Silvester* (Legs not held).—Inspiration = ¼ inch. Pointer moves slightly upwards, apparently from traction of skin in elevating arms.

2. *Marshall Hall.*—Inspiration = ⅛ inch. No movement of pointer.

3. *Silvester* (forcible, legs held).—Inspiration = 6 inches. No movement of pointer.

4. *Schultze.*—Inspiration = 2 inches. Pointer moves decidedly upwards = descent of diaphragm.

B. To eliminate the action of the expansion of the thorax, a broad band of strapping was applied, completely encircling the chest.

1. *Silvester* (forcible).—Not more than 1 inch could be inspired.

2. *Schultze.*—Results = 0.

C. Strapping removed, lungs inflated; pointer moving strongly upwards.

1. *Silvester* (legs not held).—Inspiration = 3 inches.

2. *Silvester* (forcible, legs held).—Inspiration = 5 inches.

3. *Schultze.*—Inspiration = 2 inches; distinct upward movement of pointer.

D. Strapping reapplied.

1. *Silvester* (forcible).—Inspiration = 1 inch; pointer not moving.

2. *Schultze.*—Inspiration = 1 inch; pointer ascending.

		Maximum inspired.
Order 1.	Silvester (forcible)	6 inches.
2.	Schultze	2 „

These results show that the maximum inspired under Silvester's system was far more affected by the presence or absence of the strapping than under Schultze's system; in other words, that some of the expansion of the lungs in Schultze's system is due to descent of the diaphragm.

Exp. 15 (H.).—Male child, placenta prævia. Born February 27th, 1880, 1.30 p.m.; experiment March 2nd, 2.30 p.m. (73 hours). Body very cold and stiff, thawed before fire and accidentally much scorched. Manometer adjusted. Lungs not inflated, but ineffectual attempts at artificial respiration had been made. A pointer was stuck into the liver.

1. *Pacini.*—A. (*a.*) Inspiration = 3 inches.

(*b.*) On raising the shoulders in a perpendicular direction the column sank, showing that the weight of the body of a child does not fix the trunk sufficiently.

(*c.*) On relaxing traction the fluid did not regain the level by ½ inch.

B. Manometer readjusted.

(*a.*) Inspiration = 3 inches.

(*b.*) On relaxing traction the fluid sank ½ inch below the level, showing an extra ½ inch to have been expired from the lungs.

c, *d*, *e*, *f*, precisely the same.

2. *Bain.*—Repeated experiments produced precisely the same results as the last experiments by Pacini's method.

3. *Schultze.*—Twelve experiments were tried; the amount inspired varied from 1 to 4 inches, the highest level being never maintained, the action being violent. The amount inspired was usually 1½ inch, and expiration usually carried fluid ¾ inch below zero. The actual amount of change of level being thus 2¼ inches. It was observed that when the weight of the body rested solely on the index fingers placed under the arms, ½ inch more was registered than when the other fingers supported the scapulæ. The pointer in the liver showed the diaphragm to descend by Schultze's method only.

4. *Silvester* (feet fixed).—(*a.*) Inspiration = 3 inches. Expiration = ½ inch below zero.

(*b.*) Inspiration = 3 inches. Expiration = ½ inch above zero.

Ten more experiments were tried, the amount inspired gradually diminishing, the pectoral muscles, which had been severely scorched, gradually giving way.

		Maximum inspired.
Order 1.	Schultze	4 inches (level never maintained).
2.	Bain Pacini Silvester (forcible)	3 inches.

Exp. 16 (I.).—Male child, stillborn at full time, accidental hæmorrhage. Born May 1st, 1880; experiment May 4th (about 72 hours). Manometer adjusted. Lungs not inflated.

1. *Pacini* (feet fixed).—A. (*a.*) Inspiration = 6 inches.

(*b.*) On raising the arms perpendicularly from the table the column sank (the weight of the body producing little effect).

(*c.*) On relaxing traction the column remained 2¼ inches above zero.

B. Manometer readjusted.

(*a.*) Inspiration = 5 inches, 2¼ inches having remained in lungs from last experiment.

(*b.*) On relaxing traction the column remained 1¼ inch above zero.

C. Manometer readjusted. Three experiments produced identical results with those just described (B).

(*c.*) Inspiration = 5 inches.

(*d.*) On relaxing traction the column remained ¼ inch above zero.

Three experiments produced identical results with those just described (*c*, *d*).

(*e.*) Inspiration = 5 inches.

(*f.*) Traction relaxed, level of fluid fell ¼ inch below zero.

Three experiments produced an inspiration of 5 inches, the column falling on relaxing traction to zero, or nearly.

2. *Bain.*—1st method produced precisely the same results as the later Pacini experiments (see above), repeated twelve times. 2nd method gave no results whatever.

3. *Schultze.*—Child held in expiratory posture, and manometer readjusted before each experiment.

(*a.*) Insp. = 2 inches. Exp. = 1 inch below zero.
(*b.*) ,, = 2 ,, ,, = ½ ,, ,,
(*c.*) ,, = 1½ ,, ,, = zero.
(*d.*) ,, = 4 ,, ,, = ½ inch below zero.
(*e.*) ,, = 4½ ,, ,, = zero.

(*f.*)	Insp.	=	3½ inches.	Exp.	=	zero.
(*g.*)	,,	=	gradually increasing to 5 inches	,,	=	,,
(*h.*)	,,	=		,,	=	,,
(*i.*)	,,	=		,,	=	,,
(*j.*)	,,	=		,,	=	,,
(*k.*)	,,	=		,,	=	,,
(*l.*)	,,	=		,,	=	,,

The highest level on inspiration was never maintained.

4. *Silvester* (feet fixed).—Manometer readjusted after each experiment. (*a.*) Inspiration = 4 inches. Expiration = ¾ inch above zero.

(*b.*) Inspiration = 4 inches. Expiration = zero.

(*c.*) Inspiration = 6 inches. Expiration = 1½ inch above zero.

(*d.*) Three experiments gave, inspiration = 6 inches. Expiration gradually sank from 1½ inch above zero to zero.

(*e.*) Five experiments produced, inspiration = 6 inches. Expiration = zero.

(N.B.—The later experiments would give no suspicion of pneumothorax, which was nevertheless present.)

		Maximum inspired.
Order 1.	Silvester (forcible)	6 inches.
2.	Pacini Bain	5 ,,
3.	Schultze	4½ ,, (level not maintained).

Exp. 17 (J).—Male child, full time, accidental hæmorrhage. Born May 14th, 11 a.m.; experiment May 15th, 1 p.m. (26 hours). Manometer adjusted. Lungs not inflated.

1. *Pacini.*—(*a.*) Inspiration = 6 inches. Expiration = ¾ inch above zero.

(*b.*) Inspiration = 11 inches (manometer readjusted in middle of experiment).

(*c.*) Inspiration = 9 inches. Expiration = 4 inches above zero.

(*d.*) Inspiration = 5 inches. Expiration = 1 inch below zero.

(*e.*) Inspiration = 6 inches. Expiration = zero.

(*f.*) On pressing abdomen column fell 4 inches below zero (*i.e.* total change = 10 inches).

(*g.*) Inspiration = 5½ inches. Expiration = zero.

(*h.*) On pressing abdomen column fell 3 inches below zero (*i.e.* total change = 8½ inches).

(*i.*) Inspiration = 5 inches. Expiration = 2 inches above zero.

(*j.*) Abdominal pressure depresses column to 5 inches below zero (*i.e.* total change = 10 inches).

(*Note.*—This method was repeated with the following alteration; the operator stood facing the subject and forced up the shoulders from below. The results were equally good.)

2. *Bain.*—(*a.*) Inspiration = 10 inches. Expiration = zero.

(*b.*) Inspiration = 6 inches. Expiration = 1 inch above zero.

(*c.*) Abdominal pressure depresses column 7 inches (*i.e.* total change 12 inches).

(*d.*) Inspiration = 0 (canula having become temporarily occluded by pressing against posterior wall of trachea).

(*e.*) Inspiration = 8 inches. Expiration = 2 inches below zero.

(*f.*) Abdominal pressure depresses column 4 inches (*i.e.* total change 14 inches).

(*g.*) Inspiration = 9½ inches. Expiration = 1½ inch below zero.

(*h.*) Abdominal pressure depresses column 5 inches (*i.e.* total change 16 inches).

(*i.*) Inspiration = 8 inches. Expiration = 1 inch below zero.

(*j.*) Abdominal pressure depresses column 5 inches (*i.e.* total change = 14 inches).

(*k.*) Inspiration = 8 inches. Expiration = 1½ inch below zero.

(*l.*) Abdominal pressure depresses column 3 inches (*i.e.* total change = 12½ inches).

3. *Silvester* (feet fixed).—(*a.*) Inspiration = 5 inches. Expiration = 3½ inches above zero. Abdominal pressure depresses column 8 inches (*i.e.* total change = 16½ inches).

(*b.*) Inspiration = 9 inches. Expiration = 1 inch below zero. Abdominal pressure depresses column 6 inches (*i.e.* total change = 16 inches).

(*c.*) Inspiration = 9 inches. Expiration = 1 inch below zero. Abdominal pressure depresses column 5 inches (*i.e.* total change = 15 inches).

(*d.*) Inspiration = 9 inches. Expiration = 1 inch below zero. Abdominal pressure depresses column 5 inches (*i.c.* total change = 15 inches).

4. *Schultze.*

(*a.*) Inspiration = 1 inch. Expiration = zero.
(*b.*) ,, = 2 ,, ,, = ,,
(*c.*) ,, = 3 ,, ,, = ,,
(*d.*) ,, = 4 ,, ,, = ,,
(*e.*) ,, = 2 ,, ,, = ,,
(*f.*) ,, = 3 ,, ,, = ,,
(*g.*) ,, = 3 ,, ,, = ,,
(Highest level never maintained.)

		Maximum inspired.	
Order 1.	Pacini	11 inches.	
2.	Bain	10 ,,	
3.	Silvester (forcible)	9 ,,	
4.	Schultze	4 ,,	(level never maintained).

Exp. 18 (K).—Male child, full time; presentation of hand, foot, and cord in a contracted pelvis; turning, dislocation of vertebræ at root of neck. Born May 27th, 1880, 6 p.m.; experiment May 29th, 10.30 a.m. (40½ hours). Manometer adjusted. Lungs not inflated.

1. *Bain-Pacini.*—(The methods being practically identical both in manipulation and results were classed together; the point being that, the feet being fixed, the shoulders were raised directly instead of—as in Silvester's

method—indirectly. Manometer was readjusted after each experiment.)

(*a.*) Insp. = 5 inches. Exp. = ½ inch above zero.
(*b.*) „ = 5 „ „ = ½ „
(*c.*) „ = 3 „ „ = ½ below
(*d.*) „ = 2 „ „ = ½ above
(*e.*) „ = 2 „ „ = ½ „
(*f.*) „ = 1 „ „ = ⅛ „
(*g.*) Abdominal pressure depresses column 1½ inch.
(*h.*) Insp. = 2 inches. Exp. = ½ inch above zero. Abdominal pressure depresses column 1 inch (*i.e.* total change 2½ inches).

The experiments seemed to fail from giving way of the pectoral muscles.

2. *Schüller.*—Elevating the ribs caused *depression* of the column, the ribs could not be elevated without the liver.

3. *Schultze.*

(*a.*) Insp. = 1 inch. Exp. = zero.
(*b.*) „ = 1½ „ „ = „
(*c.*) „ = 1½ „ „ = „
(*d.*) „ = 2 „ „ = ½ inch above zero.
(*e.*) „ = 1¼ „ „ = ½ „
(*f.*) „ = 2¼ „ „ = ½ „
(*Note.*—Highest level never maintained.)

Repeated experiments produced inspiration gradually reaching 3¼ inches, after which the attempts began to fail. Pneumothorax being found at the autopsy.

		Maximum inspired.
Order 1.	Bain-Pacini	5 inches.
2.	Schultze	2¼ „ (not maintained).
3.	Schüller	fall in every case.

Exp. 19. (L.).—Female child. Born June 16th, 1880, 6 p.m.; experiment June 17th, 3.30 p.m. (21½ hours). Manometer adjusted. Lungs not inflated.

1. *Bain-Pacini.*—(*a.*) Inspiration=3 inches. Expiration=zero.

(*b.*) Inspiration=4 inches. Expiration=$\frac{1}{2}$ inch below zero. Abdominal pressure depressed level $\frac{3}{4}$ inch (*i.e.* total change $5\frac{1}{4}$ inches).

(*c.*) Inspiration=4 inches. Expiration = zero. Abdominal pressure depressed level 1 inch (*i.e.* total change = 5 inches). Manometer readjusted.

(*d.*) Inspiration=4 inches. Expiration=$\frac{1}{2}$ inch above zero. Abdominal pressure depressed level 1 inch (*i.e.* total change=$4\frac{1}{2}$ inches). Manometer readjusted.

(*e.*) Inspiration = 3 inches. Expiration = zero. Abdominal pressure depressed level 2 inches (*i.e.* total change =5 inches). Manometer readjusted.

(*f.*) Inspiration = 4 inches. Expiration=zero. Abdominal pressure depressed level $\frac{1}{4}$ inch (*i.e.* total change =$4\frac{1}{4}$ inches).

2. *Silvester* (forcible).—Manometer readjusted each time.

(*a.*) Inspiration = $4\frac{3}{4}$ inches. Expiration=zero. Abdominal pressure depressed level $\frac{1}{4}$ inch more (*i.e.* total change=5 inches).

(*b.*) Inspiration = 5 inches. Expiration = zero. Abdominal pressure depressed level $\frac{3}{4}$ inch more (*i.e.* total change=$5\frac{3}{4}$ inches).

(*c.*) Inspiration = 5 inches. Expiration = zero. Abdominal pressure depressed level $\frac{1}{2}$ inch more (*i.e.* total change = $5\frac{1}{2}$ inches).

(*d.*) Inspiration = 5 inches. Expiration = zero. Abdominal pressure depressed level $\frac{1}{2}$ inch (*i.e.* total change = $5\frac{1}{2}$ inches).

(*e.*) Inspiration = 5 inches. Expiration = zero. Abdominal pressure depressed level $\frac{1}{4}$ inch (*i.e.* total change = $5\frac{1}{4}$ inches).

(*f.*) Inspiration = 5 inches. Expiration = zero. Abdominal pressure depressed level $\frac{1}{4}$ inch (*i.e.* total change =$5\frac{1}{4}$ inches).

3. *Schücking.*—Repeated experiments in which Silvester's and Schücking's methods were tried alternately, and also in which the arms were first raised, and then slightly

abducted; and thirdly first abducted and then raised simply, showed abduction to be of no additional value.

Thus Schücking's modifications possess no advantage over Silvester's original directions.

With regard to *flexion of the legs*, rather more air was inspired when the legs were straight than when they were flexed.

It is probable that this is due to the fact that where there is no opisthotonos there is no excessive tension on the anterior body walls.

4. *Schultze.*

(*a.*) Insp. = 3 inches. Exp. = zero
(*b.*) „ 4 „ „ = „
(*c.*) „ 3 „ „ = „
(*d.*) „ 4 „ „ = „
(*e.*) „ 4½ „ „ = „
(*f.*) „ 5 „ „ = „
(Highest level never maintained).

		Maximum inspired.
Order 1.	Schultze[1] Silvester[2] (forcible) Schücking	5 inches.
2.	Bain-Pacini	4 inches.

Exp. 20 (M.).—Male child, apparently full time; flooding. Born July 5th, 1880. 1 a.m.; experiment July 5th, 2 p.m. (37 hours). Manometer adjusted. Lungs carefully inflated.

1. *Bain-Pacini.*—Manometer readjusted each time. No abdominal pressure used.

(*a.*) Insp. = 6 inches. Exp. = ½ inch below zero.
(*b.*) „ = 6 „ „ = ½ „
(*c.*) „ = 6 „ „ = ½ „
(*d.*) „ = 7 „ „ = ½ „
(*e.*) „ = 5 „ „ = ¼ „
(*f.*) „ = 5 „ „ = ¼ „

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[1] Highest level never maintained.

[2] The highest level of 5 inches was reached once by Schultze's method, five times by Silvester's.

(*g*.) Abdominal pressure depressed level two inches more (*i.e.* total change 7¼ inches).

2. *Silvester.*—No abdominal pressure used, feet held.

(*a*.) Insp.=6 inches. Exp.=zero.
(*b*.) ,, =6 ,, ,, = ,,
(*c*.) ,, =6 ,, ,, = ,,
(*d*.) ,, =7 ,, ,, = ,,
(*e*.) ,, =6 ,, ,, =¼ inch below zero.
(*f*.) ,, =6 ,, ,, =¼ ,,
(*g*.) Abdominal pressure depressed level 1 inch (*i.e.* total change=7¼ inches).

3. *Schücking.*—Six experiments tried; in all inspiration =5 inches. Expiration=zero.

		Maximum inspired.
Order 1.	Bain-Pacini Silvester (forcible)	7 inches.
2.	Schücking	5 inches.

Summary of results.

EXPERIMENT 1.

	Maximum in inches.
1. Schultze-Silvester	4½
2. Silvester	2
3. Schultze	1
4. Marshall Hall	¼
5. Schroeder	0

EXPERIMENT 3.

1. Silvester	2
2. Schultze-Silvester	1¾
3. Schultze	1
4. Marshall Hall	¼ (+)
5. Howard	¼
6. Schroeder	0

EXPERIMENT 4.

1. Schultze-Silvester	1¼
2. Schultze	1
3. Howard	¼ (+)
4. Marshall Hall	¼
5. Silvester	0
6. Schroeder	0

EXPERIMENT 5.

1. Schultze-Silvester	4
2. Schultze	2½
3. Silvester	2½
4. Schroeder	0
5. Marshall Hall	0

EXPERIMENT 6.

1. Silvester (forcible)	4½
2. Schultze	4½
3. Schultze-Silvester	2½
4. Schroeder	0
5. Marshall Hall	
6. Howard	

EXPERIMENT 9.

1. Silvester (forcible)	8
2. Schultze-Silvester	7
3. Schultze	5½
4. Marshall Hall	¼
5. Howard	⅛

EXPERIMENT 10.

1. Schultze	8
2. Silvester (forcible)	8
3. Marshall Hall	¼

EXPERIMENT 11.

1. Silvester (forcible)	11
2. Schultze-Silvester	7
3. Schultze	7
4. Marshall Hall	⅞

EXPERIMENT 12.

	Maximum in inches.
1. Silvester (forcible)	8
2. Schultze	7
3. Schultze-Silvester	2
4. Marshall Hall	⅛

EXPERIMENT 13 (*Mercury*).

1. Schultze	1
2. Schultze-Silvester	
3. Silvester (forcible)	½
4. Marshall Hall	0

EXPERIMENT 14.

1. Silvester (forcible)	6
2. Marshall Hall	⅛
3. Schultze	2

EXPERIMENT 15.

1. Schultze	4
2. Bain	3
3. Pacini	
4. Silvester (forcible)	

EXPERIMENT 16.

1. Silvester (forcible)	6
2. Pacini	5
3. Bain	
4. Schultze	4½

EXPERIMENT 17.

1. Pacini	11
2. Bain	10
3. Silvester (forcible)	9
4. Schultze	4

EXPERIMENT 18.

1. Bain-Pacini	5
2. Schultze	2¼
3. Schüller	0

EXPERIMENT 19.

1. Schultze	5
2. Silvester (forcible)	
3. Schücking	
4. Bain-Pacini	4

EXPERIMENT 20.

1. Bain-Pacini	7
2. Silvester (forcible)	
3. Schücking	5

NOTE.—" Silvester (forcible) " implies the fixation of the feet.

Remarks.

The results of seventeen experiments are recorded, the remaining three experiments having failed.

The summary of results in each case has been determined not on the principle of average results, but of maximum effect produced.

To either method objections may be urged :

(*a*.) To the system of registering maximum effect, the objection seems to be that such maximum effect may have been produced in one solitary instance. A perusal of the experiments will set this right.

(*b*.) To the system of registering averages, the objection seems to be that the average amount of effect produced does not really represent the series of experiments unless these are more or less uniform, while a casual failure may bring down the average unfairly.

The determination of the value of the various methods of artificial respiration is a task which is eminently unsuited for rigid numerical statistics, even with regard to the small portion of the subject now under consideration.

It is plain from the foregoing experiments that some of the subjects afforded far better results than others ; the difference being in some cases due to the development and rigidity of the thoracic walls (which vary greatly even in mature children) ; in others to the presence or absence of mucus in the air-passages, and also no doubt in some cases to the state of preservation. In determining the relative value of the different methods, such subjects as gave high results are plainly much better guides than those which gave low results.

On looking at the table of results, it will be seen that the earlier experiments eliminated three methods as practically useless, viz. those of Schroeder, Howard, and Marshall Hall.

1. *Schroeder.*—This method seems to be based on the *à priori* reasoning that the capacity of a flexible cylinder increases when it is curved, provided that the concave side is not collapsed.

For instance, the capacity of such an instrument as a concertina, to the projecting rings of which a piece of whalebone had been fastened on one side, would be increased by curving it so as to make its outline convex on the side opposite to the whalebone.

In the body of a child, the spinal column would represent the whalebone, and the ribs the rings.

The reasons why the method fails are :

1st. That the anterior body walls become tense and approximated to the spine when the body is bent into a position of opisthotonos, the capacity of the thorax and abdomen becoming diminished.

2nd. That the ribs are not rigid even in children which have breathed.

3rd. But the principal reason lies in the fact that in children which have never breathed, the position of the thorax is one of *expiration,* and not of *inspiration;* the thoracic walls are completely collapsed, and there is no thoracic cavity or cylinder to deal with. There is nothing to procure descent of the diaphragm, and the thoracic cavity cannot be expanded in any direction by such means.

2. *Howard.*—The above fact of the collapsed state of a child's chest which has never breathed, sufficiently explains the failure of this method. Indeed, for such children certainly, and for all new-born children probably, "Howard's method" (sc. of artificial inspiration) does not exist. For adults the matter is different; in them the position of thoracic equilibrium is one of moderate inspiration, the chest walls are moreover capable of elastic recoil, and the manœuvre repeats the mechanism of respiration in birds, in which expiration requires the expenditure of vital force, inspiration being accomplished by the elastic recoil of the chest walls.

The method ought never to have been made to include stillborn children.

3. *Marshall Hall.*—The above remarks apply to this method also, which may be said to have been proved incapable of producing inspiration.

4. *Schüller.*—This method is incapable of producing inspiration; the ribs are hard to separate from the liver, and their want of firmness prejudices any effect which might otherwise be produced; moreover, groping with the finger-tips between the ribs and surface of the liver is a proceeding not altogether without risk. The bent position of the legs was shown (Exp. 19) to be of no additional value, it being probable that in the absence of opisthotonos there is no excessive tension of the anterior abdominal walls which needs avoiding.

We are left, therefore, with Silvester's method (and its modifications by Pacini, Bain, and Schücking) and Schultze's method.

The earlier experiments plainly showed that the weight of a child's body is not sufficient counterpoise to the necessary traction in Silvester's method. In all but the first few cases the feet were fixed, and only in these cases are the results compared with those of other methods. We shall first deal purely with the amount of air inspired by these different methods; reserving our remarks on their mode of action and the small details to be observed in their employment.

It will be seen that in the great majority of cases in which Schultze's method came into competition with Silvester's or its modifications, it produced less effect (Experiments 6, 9, 11, 12, 14, 16, 17, 18); in two cases Schultze's method produced the greatest result (Experiments 13, 15); in two cases the results of Schultze's method equalled those of Silvester's or its modifications (Experiments 10, 19).

It remains then to compare with each other Silvester's method and its modifications. This was done in five experiments (15, 16, 17, 19, 20).

Pacini's and Bain's methods proved practically identical and will be considered together.

Schücking's method proved practically identical with Silvester's and will be considered together with it.

Silvester's (and Schücking's) methods produced more results than Pacini's and Bain's in two cases (Experiments 16, 19).

Pacini's and Bain's produced more results in one case (Experiment 17).

The results were identical in two cases (Experiments 15, 20).

The practical result is that, provided the feet are fixed and the body properly laid, the mode of seizure (by arms or shoulders) is a matter of no moment.

We now come to the consideration of the mode of action of these methods and of some of the details of their execution.

5. *Schücking.*—This method was tested in Experiment 19, and found to possess no advantage over Silvester's.

6. *Silvester.*—The principle underlying this method and its modifications is the elevation of the ribs, clavicle, and sternum, and consequent enlargement of the cavity of the chest.

It is to be remarked that this group of manipulations, which produces the greatest amount of ventilation, in no way resembles the normal respiration of a child which is almost purely diaphragmatic.

It was shown (by Experiments 9, 10, 11, 12, 13) that, in the absence of very violent traction, the position of the arms is of much importance; the effect produced when the arm is *e*verted being more than twice as great as when the arm is *in*verted. This is no doubt due to the mode of insertion of the pectoralis major muscle into the outer lip of the bicipital groove; *e*version naturally renders this more tense. Silvester gives no directions with regard to this point. The arms should certainly be seized above the elbow.

The block beneath the shoulders should only be just so high as to prevent the chin from falling or being bent forwards on the breast; opisthotonos impedes ventilation by tension of the anterior body walls and their consequent approximation to the spine.

7. *Pacini-Bain.*—These methods being essentially identical are considered together. The mode of seizure of the shoulders was shown to be unimportant.

The amount of ventilation produced proved to be, to all practical intent, identical with that produced by Silvester's method.

One small disadvantage seems to be that the operator does not face the subject's face, but views it upside down. This is a matter not directly germane to the present enquiry, but it was thought well to test the question whether an equal amount of ventilation could be procured by reversing the action and elevating the shoulders from below, the operator facing the subject. This was answered affirmatively by Experiment 17, note.

The latter half of Pacini's method and Bain's second method, consisting in raising the arms from the ground and using the weight of the body as a counterpoise, are inapplicable to new-born children, the weight of the body being insufficient to fix it against the traction of the operator (Experiments 15, 16).

In one case the pectoral muscles seemed to give way under the Pacini-Bain manipulations, as if exposed to greater tension than by the Silvester method (Experiment 18).

8. *Schultze.*—In this most ingenious method the shoulder is grasped as in Pacini's method, the ribs, clavicles, and sternum are elevated as in Silvester's method and its modifications (especially Pacini's method), but the counterpoise, or rather the force, is furnished by the action of gravity and so-called centrifugal force, which not only procure elevation of the anterior and upper thoracic walls, but also descent of the diaphragm.

This method, being hard to describe, somewhat complicated, and almost never practised in England, requires special notice.

In the first place the seizure of the shoulders is a most important point, the object being to throw the weight at the end of the inspiratory movement entirely upon the index fingers placed in the axillæ. Attention is directed to this point in Experiment 15, where it is shown that on it depends the entrance of a considerable amount of air. No weight should be supported by the other fingers lying on the back of the thorax.

Again, the violence of its action was noteworthy; the fluid rose violently in the manometer, and never maintained the highest level reached. The following will show the difference between the levels reached and the levels maintained:

Experiment 6 (*a*), 1 inch to ½ inch; (*b*), 4 inches to 1¾ inch; Experiment 12 (*b*), 7 inches to 2 inches.

This remarkable fact requires consideration. The rapid jerk with which the fluid fell implies some elastic recoil, either of the chest walls or lung tissue. No recoil of the chest walls was observed, and there are other reasons for thinking that the cause was over-distension of the lung tissue. One reason for thinking this is that it was usually during the Schultze manipulations that the sucking noise was heard at the root of the neck, which was found to have been due to entrance of air beneath the deep cervical fascia into the anterior mediastinum, and sometimes into the pleura. This subject will receive attention hereafter, the only point here insisted on being that this can only be explained by a greater expansion of the chest walls than the lungs were capable of following, and consequent entrance of air into the thoracic cavity by the route of least resistance.

It must be remembered that a small plug of mucus is sufficient to occlude a comparatively important bronchus in a child, and it is suggested that in the presence of a very rapid and powerful blast into the lungs, a neighbouring lobule or bronchus (with its now very delicate walls) may rapidly dilate and press upon the original seat of obstruction, thus completing the occlusion. Under such circumstances the conditions would correspond with those of collapse of part of the lungs with violent inspiratory efforts, which always procure over-distension of other parts of the lungs. Some such explanation seems needed when we remember the incomplete expansion of the lungs proved by dissection. This is a circumstance which, it must be owned, is not in favour of the method.

It must be observed that this may produce the retraction of the abdomen observed by Behm, just as much as occlusion of the glottis by the tongue may produce it.

Schultze's claim to have detected small atelectasies, and to have proved their removal by percussion several days after birth, should be considered in the presence of the actual lungs of a stillborn child ('Der Scheintod Neugeborener,' p. 172).

In the course of the experiments it suggested itself to try suspending the child by its arms instead of by its armpits. Such experiments are designated "*Schultze-Silvester*" in the descriptions. It was found that more air was introduced in this way than by Schultze's method, no doubt from greater tension of the pectoral muscles and greater elevation of the shoulders.

The manœuvre is hardly one which could be safely applied to a slippery living child. It is, however, of interest in itself.

The question of the actual descent of the diaphragm was tested by passing a pointer through the abdominal walls into the liver. Descent of the diaphragm naturally implies descent of the liver and ascent of the pointer.

Schultze's method certainly procures descent of the diaphragm, as will be seen from Experiments 14 and 15. No other method does this.

How much ventilation is due to descent of the diaphragm?

Experiment 14 was designed with a view to answering this question. A broad band of strapping was tightly applied to the thorax so as to completely encircle it, with a view to preventing its expansion; it was afterwards removed, then reapplied, and the results compared. It is almost needless to say that the strapping seriously hindered the action of Silvester's method, reducing the column of fluid from 6 inches to 1 inch, although much force was applied.

Schultze's method raised a column of 2 inches before the strapping was applied; after the application of the strapping the results became *nil.* The strapping was then removed, and a column of 2 inches raised again. On reapplying the strapping a column of 1 inch was raised, the pointer indicating some descent of the diaphragm.

On blowing directly into the lungs the pointer moved far more than it ever did with Schultze's method. The diaphragm then does descend in Schultze's method, but ventilation depends probably far more on elevation of the ribs, &c., as in other methods.

It is very remarkable how much ventilation is effected by Silvester's method and its modifications, when it is remembered that it is procured by a mode utterly unlike the natural respiration of a new-born infant.

While these experiments were still proceeding, a valuable paper appeared from the pen of Carl Behm ("Die verschiedenen Methoden der kunstlichen Athmung bei Asphyctischen Neugeborenen," 'Zeitschrift für Geburtshülfe und Gynäkologie,' Band v, Heft i, 1880, p. 36). His conclusions are founded on experiments performed on six subjects, only three of whom had never breathed, and in one of the latter the experiments failed. They therefore depend on six cases, only two of which fulfil the necessary conditions.

In some cases his conclusions agree with mine; in some they differ essentially; a difference which I believe to be due to the facts above mentioned. The essential difference between the conditions of equilibrium of a child's chest before it has breathed and after cannot be too strongly insisted upon. This difference is probably established in a very short time after birth, and entirely alters the conditions, especially with regard to the first group of methods, depending on elastic recoil of the chest walls (Marshall Hall, and Howard).

It will be seen that both these methods in my cases amounted to absolute failures, while in Behm's cases they several times surpassed other methods (as those of Schultze, Silvester, and its modifications). If we look, however, at the only two of his cases which concern stillborn children who had never breathed (Cases 2 and 6), we find that in Case 2 Marshall Hall's method gave no results (Howard's not being tried); and that in the other case (Case 6) Marshall Hall's and Howard's methods produced hardly any result, standing at the bottom of the list, with the exception of Schüller's method, which is valueless.

Of his other cases the following were the ages at death:—Case 1, one month; Case 3, one day; Case 4, nine days. In two of these cases (1 and 3) the elasticity of the ribs is described as "good," in the other (Case 4) as "weak."

Attention should be especially called to the fact that a child's thorax can be fairly resilient a day after birth. But the question is not what results would be obtained even so short a time as a day after birth, but what amount of ventilation each method will produce in a child which has never breathed. No doubt all methods are far less efficacious in ill-developed and premature, than in well-developed and mature, children.

We therefore venture to think that if Behm's cases are properly considered, they tell in favour of the view above enunciated, that all methods depending on the elastic recoil of the chest walls are useless when applied to really stillborn children as means of ventilation of the lungs.

It must always be remembered that a great source of difficulty in the living child (the patency of the air-passages) is secured in these experiments by tracheotomy; and this point has to be considered in choosing a method or methods for the recovery of a stillborn child, a question which is far from being settled by the present purely experimental inquiry.

Behm recommends (p. 44) the legs to be bent and the feet not fixed (as recommended by Schüller). The bending of the legs I have shown to be of no moment (Experiment 19), the fixation of the legs I have proved to be quite necessary to produce considerable effect.

Behm found, as I did, the Silvester group of manipulations capable of producing greater ventilation than that of Schultze.

It is easily intelligible that the fact of real stillbirth in the subjects experimented on would affect these far less than the methods of Marshall Hall and Howard, and indeed, be perhaps in their favour.

The methods of faradisation of the phrenic nerves (Hufeland, 'Dissertatio vir. electr. in Asphyxia.' Göttingen, 1793) (and that of Woillez, 'Du Spirophore, appareil de sauvetage pour le traitement de l'Asphyxie.' Paris, 1876; 'Bulletin de l'Acad. de Méd.,' Nos. 25, 31, 32, 36, 37, 38; 'Comptes Rend.,' lxxxii, p. 1447), the principle of which is alternate rarefaction and condensation of the air in the receiver of an air-pump in which the patient is immersed up to the neck, have not been included, the first because it cannot be tried on dead bodies, the second because it requires a large and elaborate apparatus which renders it practically useless.

Conclusions.

The following conclusions are offered:

1. Since the position of equilibrium of a stillborn child's chest is one of absolute expiration, airlessness, or collapse; no method which depends on elastic recoil of the chest walls will introduce air into its lungs. The methods of Marshall Hall and Howard are useless as means of directly ventilating the lungs of stillborn children.

2. Silvester's method and its modifications by Pacini

and Bain introduce more air into the lungs than any other method.

3. In using Silvester's method the arms should be held above the elbows and everted.

4. In using Pacini's or Bain's method the legs should be fixed, the second half of Pacini's method and Bain's second method should not be employed, as the weight of a new-born child's body is insufficient counterpoise to the necessary traction.

5. In using these two latter methods, the operator may face the subject, and lift the shoulders from below; by this means he is able to watch the child's countenance, and is able to introduce an equal quantity of air.

6. Schücking's method is no improvement on Silvester's.

7. Schüller's method is useless and not free from risk.

8. Schroeder's method is useless.

9. Schultze's plan, although its power of ventilation is less than that of Silvester and its modifications, yet acts efficiently.

10. In Schultze's method the diaphragm does descend though but slightly; its principal action, however, is on the thoracic walls as in the Silvester group.

11. In Schultze's method it is important that the whole weight should rest (at the end of the inspiratory movement) on the index fingers in the axillæ, and should not be distributed to the other fingers.

12. The violence of the action of the method of Schultze is not in its favour.

13. Opisthotonos always produces expiration by tension of the anterior body walls, and should be avoided.

It has been thought unnecessary to include statistics with regard to the expiratory force of each method; considering that direct pressure amounting to any desired force can be applied in all cases where the posture is horizontal. The method of Schultze possesses considerable expiratory force.

SECOND COMMUNICATION

ON

ARTIFICIAL RESPIRATION IN STILLBORN CHILDREN.

THE EXPANSIBILITY OF VARIOUS PARTS OF THE LUNGS.

AN EXPERIMENTAL INQUIRY.

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Preface.

The present communication being one of a series on the subject of Artificial Respiration in Stillborn children proposes to deal with the question, "which part of the lungs of a child which has been subjected to various methods of manipulation with this object is most frequently expanded and which most frequently unexpanded?"

It would have been interesting to answer this question for each separate method, but material is not plentiful enough. Nothing short of a series of observations on the appearances in a considerable number of cases manipulated by each method would suffice for a satisfactory answer to this subdivision of the question.

Moreover, it is probable that all the methods which are effectual in producing inspiration would be found to produce aëration of very much the same parts of the lungs, since they all act principally in the same way, namely by raising the ribs, clavicles, and sternum.

Even the method of Schultze, which does produce some descent of the diaphragm, still acts principally in the same way as the Silvester group, as I have elsewhere shown.

It would also be very interesting to determine the order in which various parts of the lungs become expanded by inspiring any desired quantity of air.

Unfortunately this is beyond our power; the bodies of stillborn children possess (so to say) individual peculiarities, and some lend themselves much more favourably to experiments than others.

It would have been easy to remove the respiratory organs or open the thorax, and force a measured quantity of air into the chest, observing the order of expansion of the several parts, but the conditions would be so essentially changed, both as regards the method of aëration and the surroundings of the lungs, that the similarity between artifice and nature would cease, and the investigation possess little probable and absolutely no demonstrable value.

This question, however, is more or less elucidated by the following experiments, in which the amount of air changed can be compared with the condition of the lungs as shown by dissection.

In the first table the first column shows the reference to the experiment, the second the methods of manipulation employed, the third the amount of air changed, and the fourth the conditions of the thorax as shown by dissection.

With regard to the amount of air changed, it may be necessary to say that where abdominal and thoracic pressure was employed for the purpose of expelling as much air as possible, the amount of aëration is calculated from the air they expelled as well as from the height of the column of fluid drawn up by inspiration.

This air is of course not under equal pressure, as would have been the case with a spirometer, but the figures are sufficiently near to give an idea of the amount of air received by the lungs in each case.

It may be added that the experiments were instituted with a view to ascertaining the inspiratory value of the different methods, and have been utilised for the present inquiry.

The use of a spirometer would have prevented several important observations, such as the force with which the air is inspired under Schultze's method.

Although twenty-six subjects were experimented on, only such experiments as refer to our subject are here recorded; and no case has been quoted in which direct inflation of the lungs was practised.

The observations quoted are twelve in number.

The second table, referring to the same experiments, needs no additional explanation.

TABLE I.

No. of experiment.	Methods employed.	Maximum inspiratory effect.	Autopsy.
5	Marshall Hall.........	0	*Left lung.*—All parts contain air; most expanded part, anterior portion of upper lobe; next to this, posterior part of base of lower lobe; least expanded part is the "lingula." *Right lung* more uniformly distended; middle lobe most expanded. Every lobe floats in water. Of the right lung the most buoyant lobe is the middle, then the lower, then the upper; of the left lung the more buoyant lobe is the upper. Several small portions of both lungs do not float alone, among them the left apex. The most expanded portion of the whole lungs is the anterior part of the left upper lobe.
	Silvester	2½ in. 5 cc.	
	Schroeder	0	
	Schultze	2½ in. 5 cc.	
	Schultze-Silvester	4 in. 8 cc.	
8	Marshall Hall.........	0	Mediastinal emphysema and double pneumothorax. *Left lung* airless. *Right lung.*—All the middle lobe and upper and inner edge of lower lobe fully inflated, the rest airless.
	Silvester (forcible)	6 in. 12 cc.	
	Schroeder	0	
	Schultze	3 in. 6 cc.	
9	Marshall Hall......	¾ in. 1·5 cc.	*Left lung* completely inflated, except a patch along anterior inferior edge, which was partially inflated. *Right lung* completely inflated, but lower lobe less than the rest.
	Silvester (forcible)	6 in. 12 cc.	
	Schultze	5½ in. 11 cc.	
	Schultze-Silvester	7 in. 14 cc.	
	Howard	⅛ in. 0·25 cc.	
10	Marshall Hall......	½ in. 1 cc.	*Left lung* floats as a whole, but upper lobe sinks; lower lobe floats, apex sinks; lingula floats with difficulty; lower lobe more buoyant than lingula. *Right lung* floats as a whole; both lobes (there is no middle lobe) float at first, but upper lobe soon sinks; left lower
	Silvester (forcible)	8 in. 16 cc.	
	Schultze	8 in. 16 cc.	

No. of experiment.	Methods employed.	Maximum inspiratory effect.	Autopsy.
			lobe is less buoyant than right lower lobe. No lobe of either lung is thoroughly inflated.
11	Marshall Hall...... Silvester (forcible) Schultze	$\frac{7}{8}$ in. 1·75 cc. 11 in. 22 cc. 7 in. 14 cc.	Mediastinal emphysema, right pneumothorax. *Left lung* floats as a whole; each lobe floats, the lower lobe the better; apex is airless; of lower lobe, lingula floats best, posterior part of base worst. *Right lung* floats as a whole; upper lobe sinks apex downwards, the other lobes float; apex airless; middle lobe floats best; posterior part of base is airless.
12	Marshall Hall...... Silvester (forcible) Schultze .... Schultze-Silvester	$\frac{1}{8}$ in. 0·25 cc. 8 in. 16 cc. 7 in. 14 cc. 7 in. 14 cc.	Mediastinal emphysema, left pneumothorax. *Left lung* sinks as a whole; upper lobe airless; lower lobe floats, but when divided the lingula floats, the rest sinks. *Right lung* floats as a whole, anterior surface uppermost; all the anterior surface fairly inflated, the rest airless; lower and middle lobes float; upper lobe sinks, and is nearly airless.
13 Mercury manometer	Marshall Hall......... Silvester (forcible) Schultze .... Schultze-Silvester	0 $\frac{1}{2}$ in. 1 cc. 1 in. 2 cc. 1 in. 2 cc.	*Left lung* quite airless. *Right lung.*—A few inflated lobules along lower front edge of upper lobe and extreme inner part of this border, and at corresponding point of middle lobe; lower lobe contains most air, then upper lobe; lower lobe partly inflated along anterior surface and along upper and lower edges.
E.	(Child laid on its face after death)[1] Silvester forcible)	...	Both lungs mostly inflated, right more than left. *Left lung* all inflated, except a vertical strip lying alongside vertebral column from apex to base, and a small patch of upper lobe just anterior to root. *Right lung* all inflated, except a patch of lower lobe just anterior to root.

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[1] The object was to see whether posture had anything to do with the matter, allowing the blood to gravitate to the front instead of to the back of the lungs.

No of experiment.	Methods employed.	Maximum inspiratory effect.	Autopsy.
			Each lung floats as a whole, but the above-named airless parts sink when separated.
G. (14)	Silvester (forcible) Marshall Hall…… Schultze …………	6 in. 12 cc. ⅛ in. 0·25 cc. 2 in. 4 cc.	Mediastinal emphysema, no pneumothorax. Both lungs expanded; least inflated part being two strips running vertically along the back, opposite the angles of the ribs.
J. (17)	Pacini …………… Bain……………… Silvester (forcible) Schultze …………	16 in. 32 cc. 16 in. 32 cc. 16 in. 32 cc. 4 in. 8 cc.	*Left lung* floats; both lobes separately float; all parts well expanded except lower and posterior edge of upper lobe and a line along the costal angles of the lower lobe, which is quite airless, and sinks. *Right lung* florid and expanded; one or two airless patches, the largest along the costal angles of the lower lobe.
K. (18)	Pacini-Bain …… Schüller …………… Schultze …………	5 in. 10 cc. 0 2¼ in. 4·5 cc.	Mediastinal emphysema, right pneumothorax. *Left lung.*—Anterior inferior part of upper lobe and lingula fairly expanded; front of lower lobe fairly expanded; lowest part of base posteriorly fairly expanded. *Right lung* airless.
L. (19)	Pacini-Bain …… Silvester (forcible) Schücking ………… Schultze …………	5½ in. 11 cc. 5¾ in. 11·5 cc. Do. 5 in. 10 cc.	Mediastinal emphysema, no pneumothorax. *Left lung* quite airless. *Right lung* airless, except middle lobe and anterior internal part of lower lobe. At anterior internal part of middle lobe is a patch of subpleural emphysema.

Table II.

No. of experiment.	Left lung.		Right lung.		
	Upper lobe.	Lower lobe.	Upper lobe.	Middle lobe.	Lower lobe.
5	Anterior surface best expanded of all parts of lungs; apex not floating	Posterior part of base well expanded; lingula least expanded	Least expanded	Most expanded	Fairly expanded.
8	Mediastinal emphysema and double pneumothorax.				
	Airless		Airless	Well expanded	Upper and inner edge well expanded; the rest airless.
9	Completely expanded	Completely expanded; except a patch on anterior inferior edge	Completely expanded	Completely expanded	Less well expanded.
10	Sinks in water	More buoyant than upper lobe (lingula hardly floats); less buoyant than right lower lobe	Less buoyant than lower lobe; soon sinks	Absent	More buoyant than right upper or left lower lobe.
11	Mediastinal emphysema; right pneumothorax.				
	Less buoyant than lower lobe; apex airless	More buoyant than upper lobe; lingula best expanded; posterior part of base least expanded	Sinks in water; apex airless	Best expanded	Floats; posterior part of base airless.
12	Mediastinal emphysema; left pneumothorax.				
	Sinks as a whole.		Floats as a whole.		
	Airless	Floats; but when divided lingula floats, the rest sinks	Nearly airless; part of anterior surface inflated, the rest airless	Floats; anterior surface inflated, the rest airless	Floats; anterior surface inflated, the rest airless.

No. of experiment.	Left lung.		Right lung.		
	Upper lobe.	Lower lobe.	Upper lobe.	Middle lobe.	Lower lobe.
13	Quite airless		A few inflated lobules along lower anterior edge and inner part	A few inflated lobules at inner extremity of upper anterior border; the least expanded of the three lobes	Partly inflated along anterior surface and upper and lower edges; the best expanded of the three lobes.
E	Less expanded than right		More expanded than left.		
	All expanded except vertical strip along angles of ribs, and a small patch anterior to root	All expanded except vertical strip along angles of ribs.	Completely expanded	Completely expanded	All expanded except a patch anterior to root.
G (14)	Mediastinal emphysema, no pneumothorax.				
	Well expanded, except a vertical strip along angles of ribs behind.		Well expanded, except a vertical strip along angles of ribs behind.		
J (17)	Well expanded, except lower and posterior edge	Well expanded except line along costal angles behind	Well expanded	Well expanded	Well expanded except patch along costal angles.
K (18)	Mediastinal emphysema; right pneumothorax.				
	Anterior inferior part fairly expanded	Lingula front and posterior inferior border fairly expanded	Airless	Airless	Airless.
L (19)	Mediastinal emphysema; no pneumothorax.				
	Airless	Airless	Airless	Partly expanded; at anterior internal part a patch of subpleural emphysema	Airless except anterior internal part.

Remarks.

Mediastinal emphysema occurred in six cases; in four cases with pneumothorax

Pneumothorax of the four cases: one affected both pleural cavities, two the right, one the left.

In all cases the lung on the side of the pneumothorax was less expanded than the other.

The pneumothorax was probably partly the cause and partly the effect of the complete or incomplete collapse of the lung. Pneumothorax of course impedes the expansion of the lung. On the other hand, the rupture will probably occur into that side on which the lung expands the less, the pressure being greater on that side.

This subject will hereafter be treated more particularly.

In seven cases one lung could be said to be generally better expanded than the other.

In six cases the right was the better expanded, in one the left.

The apices were frequently the least expanded parts of the lungs, *e. g.* No. 5 both apices; No. 8 right; No. 10 both; No. 11 both; No. 12 left; L. (19) right.

The anterior surfaces were frequently better expanded than the posterior surfaces, *e. g.* No. 5 left upper lobe; No. 12 whole of right lung; No. 13 whole of right lung; K. (18) left lung; L. (19) middle and lower lobes.

In several of these cases the expanded patch was not bounded by lobes, but extended over the fissures to adjacent lobes, *e. g.* No. 12 whole of right lung; No. 13 right lung; K. (18) left lung; L. (19) middle and lower lobes.

In several cases an unexpanded strip lay vertically along the costal angles on each side of the vertobral column, *e. g.* E. left lung; G. (14) both lungs; J. (17) lower lobes both lungs.

In two cases these strips were not limited by lobes but crossed the fissures, *e. g.* E.; G. (14).

In one case, J. (17), the strip was seen on both lower lobes.

In some cases the lingula was better expanded than the rest of the left lung, *e. g.* 11; 12; K. (18).

In two cases it was airless or little expanded, *e. g.* 5; 10.

In no case was the posterior aspect of the lung generally better expanded than the anterior aspect, indeed, in one case (in which, with a view to testing whether the more frequent expansion of the anterior aspect of the lungs was due to supine decubitus after death, and consequent hypostatic gravitation of blood to the posterior aspect) the unexpanded vertical strip along the angles of the ribs was particularly well marked (Exp. E.).

On the whole it may be said that the parts of the lungs most frequently and thoroughly expanded were the anterior surfaces, not including the apices or anterior inferior edges.

The parts less frequently and thoroughly expanded were the apices, lower edges, and the vertical strips along the angles of the ribs posteriorly.

The more frequent and thorough expansion of the right lung may be due to the greater directness and size of the right bronchus.

These conclusions are very interesting, and can be accounted for.

First, the fact of the frequent non-expansion of the apices shows that the distance from the trachea does not explain the phenomena. Again, no doubt plugs of mucus will account for some of the unexpanded patches, but they will not explain the greater frequency of their occurrence in certain regions. Moreover the very distribution of many of these expanded and unexpanded patches disproves such cause, inasmuch as patches due to the patency or closure of a tube would be *limited to a lobule* or *lobe*.

Now we have seen that these patches are distributed irrespective of fissures and lobes; therefore some other cause must be found.

This cause is, we think, to be found in the mobility of various parts of the chest walls.

The contents of the thorax are not under the conditions of fluid in a vessel, and the laws of equal pressure do not apply. If the chest walls are elevated in one part the external pressure opposite that spot is diminished, and the air will tend to expand the subjacent lung by preference.

On the other hand, the least mobile parts of the chest walls should overlay the least expanded parts of the lungs.

To apply these principles to the matter in hand. The most efficient methods of artificial respiration (viz. the Silvester group and the method of Schultze) act principally by elevating the ribs, clavicles, and sternum.

In a new-born child the upper ribs are hardly at all mobile, and the lower ribs are by far the most mobile. It is beneath the lower ribs, then, that the lungs should be most expanded, and this is the case; the action will be less at the diaphragm than a little remote from it, as the diaphragm acts little in Schultze's methods, and not at all in the Silvester group; and this is also the case. In one instructive case, L. (19) the situation selected for a solitary patch of subpleural emphysema was the anterior internal part of the middle lobe of the right lung.

Again the "indifference-point," or centre of motion for each rib is near its angle, and these very points form a vertical line along the spine which we have shown to very usually overlay two unexpanded vertical strips of lung.

How far these observations agree with the appearances in children which have breathed naturally we shall hereafter try to show; meanwhile, it may be remarked that these vertical strips occupy the very same situation as collapsed lung so often does in children, and that the lower edge of the anterior surface of the lungs, occupying as it does the sulcus between the ribs anteriorly and the diaphragm inferiorly, is dependent for its expansion on a consentaneous action of the diaphragm and muscles moving the chest walls, and is often unexpanded. It has been elsewhere remarked that the mode of respiration by any of the efficient methods (Schultze's and the Silvester group), acting as it does by elevating the anterior thoracic walls, differs essentially from the natural mode of respiration in a new-born child, which is all but purely diaphragmatic.

The only considerable collections of the post-mortem appearances of the lungs of new-born children which I have been able to find are those of Joerg and Schmitt.

Out of Schmitt's 101 cases, 36 have been selected as bearing on the question and analysed; out of Joerg's 19 cases 16 have been selected and similarly treated.

The results are stated in the annexed tables, which have been compiled from positive statements only. The descriptions do not admit of more exact tabulation, being for the most part very brief.

The statements of Paris and Fonblanque, Bednar, Legendre, Gerhardt, Köstlin, Olshausen, Schwartz, and Böhr are either too inexact or are founded on too few cases to carry much weight.

Analysis of Schmitt's cases.

	Best expanded.	Least expanded.
Right lung	11	1
Left lung	3	4
Anterior surface	1	0
Posterior surface	0	2
Right upper lobe	9	3
Left upper lobe	7	4
Right middle lobe	9	3
Right base	2	12
Left base	3	9

Total cases = 36 out of 101, no cases in which inflation was practised being included.

Analysis of Joerg's cases.

	Best expanded.	Least expanded.
Right lung	4	0
Left lung	1	3
Anterior surface	1	0
Posterior surface	0	1
Right upper lobe	1	3
Left upper lobe	2	0
Right middle lobe	1	3
Right base	1	4
Left base	1	4

16 cases selected out of 19.

Analysis of cases of Schmitt and Joerg.

	Best expanded.	Least expanded.
Right lung	15	1
Left lung	4	7
Anterior surfaces	2	0
Posterior surfaces	0	3
Right upper lobe	10	6
Left upper lobe	9	4
Right middle lobe	10	6
Right base	3	16
Left base	4	13

52 cases selected out of 120.

The results are that in *children which have died soon after birth :*

1. The right lung is usually better expanded than the left.

2. The anterior surfaces are usually better expanded than the posterior.

3. The lower lobes are the parts most often unexpanded.

4. The right middle lobe is usually well expanded.

5. The part of the left lung corresponding to the right

middle lobe is often better expanded than the rest of the left lung; when the right middle lobe, on the other hand, is ill expanded, the corresponding part of the left lung is often unexpanded also (Joerg, No. 1, Case 5; No. 2, Case 6).

It is remarkable that in children who have breathed naturally the bases are so often unexpanded; but this seems to correspond with the fact that the characteristic of feeble breathing in infants is feeble descent of the abdominal viscera, betokening feeble descent of the diaphragm.

Conclusions.

The following conclusions are offered:

In stillborn children which have been manipulated by the various efficient methods of artificial respiration:

1. The right lung is more usually and more completely expanded than the left.
2. The anterior surfaces are more usually and more completely expanded than the posterior.
3. The apices of the upper lobes are often unexpanded.
4. The anterior inferior borders the same.
5. One of the places of selection for atelectasis is a strip running vertically along the angles of the ribs on each side of the spine.
6. The patches of expansion or atelectasis, when considerable, are not confined to lobes nor bounded by fissures.
7. The last circumstance is not due to obstruction of the bronchi.
8. The spots of predilection for expansion or atelectasis underlie the regions of greatest and least movement of the chest walls.

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